SIMULATION OF HYBRID INDUCTION HEATING DISTILLATION FOR WATER-OIL MIX IN REFINERY POND UTILITIES

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TALHAH-ABDULLAH B. AMIR

A thesis submitted in fulfillment of the
requirements for the award of the degree of
Bachelor of Chemical Engineering (Gas Technology)

Faculty of Chemical and Natural Resources Engineering
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To my beloved parent, wife and siblings

ACKNOWLEDGEMENTS

I would like to sincerely thank to my supervisor, Sir Mohd Zulkifli bin Mohamad Noor for his ultimate guidance, teaching, support, information and informative advice throughout the preparation and understanding this proposal report

I also take this opportunity to express my feeling gratitude to my beloved colleagues from Faculty of Chemical Engineering and Natural Resources who were respondents of this study, for their co-operation upon completion of this study

Finally, I rise my thank and praise to the Almighty Allah for giving me good health, clear mind and determination to complete this proposal report writing for Undergraduate Research Projects successfully.

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ABSTRACT

The research project is mainly about the application of hybrid induction heating distillation for oil recovery process. . The objective of this study is to investigate the effectiveness of hybrid separation phenomenon by applying induction heating in distillation process. The scopes of this study are to study the reliability of Hybrid Induction Heating Distillation in water oil distillation, to study the amount of energy used for both typical and hybrid induction heating distillation and to study the effect of temperature to the heat change The induction heating concept will be applied into this research because of the characteristics of this concept will be improved the distillation processes. Induction heating is one of a method which providing fast, consistent heat for manufacturing applications which involved bonding or changing the properties of metals or other electrically conductive materials. Technically, induction process releases a quick heating because of the high power density installation. So, it offers the possibility to reach very high temperatures. The most important is, inducting heating can reduce the electrical energy consumption because of induction installations generally have a good efficiency. So then, there are two kinds of method will be carried out in this project, which are the induction heating technique and also the typical distillation technique. Then, the results of these kinds of methods will be comparing to determine the best results. Therefore, we expect that the high quality of the oil is recovered by using induction heating technique and also the temperature of the system can be controlled orderly by using this technique.

CHAPTER 1

INTRODUCTION

1.1   BACKGROUND OF STUDY

The distillation process has been known and used for million years. The first clear evidence of distillation comes from Greek alchemists working in Alexandria in the first century AD. Distilled water has been known since at least ca. 200 AD, when Alexander of Aphrodisias described the process. Arabs learned the process from the Egyptians and used it extensively in their chemical experiments Although initially has been used as a method of producing alcoholic beverages like whisky and vodka, distillation also works as a technique of oil purification or oil recovery.

Oil recovery or also referred to the recovery of crude oil from the crude oil-water emulsion. Crude oil - water emulsions occur in many stages during oil production. The main task in offshore oil and gas production is to separate the gas, oll and water phases and to treat the individual phases in order to meet the product specifications. In spite of the great importance of this field, only few scientific studies have been conducted so far. The opaqueness and the variation in the properties of the crude oils are some of the difficulties associated in the characterisation, emulsion formation and measurement of the separation behaviour of crude oil - water emulsions.

1.2   PROBLEM STATEMENT

Continued advances in technology have increased the demand of crude oil. Crude oil must firstly separate from the water or normally know as crude oil-water emulsion. Current distillation process uses huge certain amount of energy. In order to develop more sustainable and economic production processes for chemical and pharmaceutical products, the focus on academic and industrial research is presently

set on the investigation of hybrid separation processes (P. Kreis and A. Go' Rak 2006). Thus, the distillation process assisted by induction heating should be one of method to produce high purity of crude oil. Therefore, it is importance to investigate the effectiveness of hybrid separation phenomenon by applying induction heating in distillation process.

1.3   RATIONALE AND SIGNIFICANCE

The significant highlighted in this project are, by using hybrid induction heating distillation, it has a high potential in reducing the energy consumption and system maintenance since hybrid induction heating technique is very quick responses and have good efficiency, high power density and release a quick heating, can accelerate the heating speed and reduce the time consume for the distillation process. Therefore, the cost of distillation process and also the cost of production will have high potential to decrease

1.4   OBJECTIVE

The objective is

- To investigate the effectiveness of hybrid separation phenomenon by applying induction heating in distillation process
- To study the reliability of Hybrid Induction Heating Distillation in water oil distillation

1.5   SCOPE OF STUDY

Based on the objective, the scopes of study are highlighted as follows:

- To study the heat effect of temperature to the heat change
- To study the amount of energy used for both typical and hybrid induction heating distillation
- To study the reliability of Hybrid Induction Heating Distillation in water oil distillation

CHAPTER 2

LITERATURE REVIEW

2.   INTRODUCTION

Crude oil or petroleum is a naturally occurring, flammable liquid consisting of a complex mixture of hydrocarbons of various molecular weights and other liquid organic compounds, that are found in geologic formations beneath the Earth's surface. Crude oil contains many useful component in various sector, in extracting the useful product, crude oil undergo the separation process due to the different in its component boiling point. This process also known as the oil refinery process. The aim of an effective refining process is to reduce the water content in oil to a level as low as possible. Crude oils often contain a significant proportion of water. Therefore, the heart of a refinery process is the distillation process. In a modern economic era, distillation process has many techniques. The better the technique, the efficient it would be. (Source from http://www.opus.net)

2.2   DISTILLATION PROCESS

Christe John Geankoplis stated that "The separation process known as distillation is a method for separating the various components of a liquid solution which depends upon the distribution of these components between a vapor phase and a liquid phase". Therefore, distillation process has been used widely in the chemical, petrochemical, refining and even in food industries for the separation of liquids or vapor mixture of substances. However, this process demands large inputs of energy, and even small improvements can save large amounts of energy (de Koeijer and Rivero, 2003). Distillation is the separation method that most frequently applied in the chemical industry, which is based on the difference of the volatility of the components of a liquid mixture. Because of high demand of energy, the optimal

design and operation of the distillation columns is a very important issued (B. Kotai et al., 2006).. The proper selection of the technology after consideration of the economical, technological and energy resources on site is important (Armenta-Deu., 2001). Therefore, the purpose of this study is to produce high purity oil recovered without using huge amount of energy by assisted the induction heating process.

2.2.1   Distillation for compound identification

2.2.1.1 Boiling point determination

The organic teaching labs employ distillation process routinely, both for the identification and the purification of organic compounds. Furthermore, the boiling point of a compound determined by distillation is well-defined and so it is one of the physical properties of a compound by which it can be identified. Then, distillation is used to purify a compound by separating it from a non-volatile or less-volatile material. This is because the different compounds often have different boiling points, the components often separate from a mixture when the mixture is distilled.

The boiling point actually is the temperature at which the vapor pressure of the liquid phase of a compound equals to the external pressure which acting on the surface of the liquid. Then, the external pressure is usually the atmospheric pressure. For instance, considered a liquid is heated in an open flask. Then, the vapor pressure of the liquid will enhance as the temperature of the liquid increases, and when the vapor pressure equals the atmospheric pressure, the liquid will boil. Besides that, different compounds boil at different temperatures because each has a different, characteristic of vapor pressure; compounds with higher vapor pressures will boil at lower temperatures.

Then, boiling points are usually measured by recording the boiling point (or range) on a thermometer while performing a distillation. This method is used when there are enough of the compounds to perform a distillation process. The distillation is a one method of boiling point determination measures the temperature of the vapors above the liquid. Since these vapors are in the equilibrium with the boiling liquid, they are the same temperature as the boiling liquid. Then, the vapor

temperature rather than the pot temperature is measured because if we put a thermometer actually in the boiling liquid mixture, the temperature reading would likely be higher than that of the vapors. It is because the liquid can be superheated or contaminated with other substances, and therefore its temperature is not precise measurement of the boiling temperature.

2.3 CRUDE OIL

Crude oil is a mixture of a large amount of hydrocarbons, varying amount of waxes and low content of asphaltenes (Johansen et al., 1988). The carbon content normally is in the range of 83-87%, and the hydrogen content ranges from 10-14% (Sjöblom et al., 2002). In addition, small amounts of nitrogen, sulfur, oxygen, nickel and vanadium may be found in the crude oils (Sjöblom et al., 2002). Crude oils from different regions have different properties (Elsharkawy et al., 1995).

Table 2.1: Composition by weight of the proportion of chemical elements

Element	Percentage range
Carbon	83 to 87 %
Hydrogen	10 to 14 %
Nitrogen	0.1 to 2 %
Oxygen	0.05 to 1.5 %
Sulfur	0.05 to 6.0 %
Metals	< 0.1 %

Source : Konstantin Panoussopoulos 1998, Separation crude oil- water emulsions

2.3.1 Density

Density is mass per unit volume of oil and can also be expressed as specific gravity (Cormack, 1999), which is the number of times the oil is more or less dense than fresh water (density of water = 1g/ml, 1kg/l) (Cormack, 1999). All oils have

specific gravity less than 1.00 with exception of some heavy crude oils (Doerffer, 1992). The American Petroleum Institute has developed the API gravity scale which expresses the ratio of weights of equal volumes of oil and pure water at a temperature of 16 °C and one atmosphere pressure (Doerffer, 1992). Generally, the dense oil is more viscous, less volatile and has high specific gravity and lower API gravity (Cormack, 1999; Doerffer, 1992).

2.3.2 Volatility

It is the ease by which the components of the oil are lost to the atmosphere due to evaporation (Cormack, 1999). It is represented as the percentage of the total oil evaporated at different temperature ranges (Cormack, 1999). The rate and extent of loss of volatiles depends upon surface to volume ratio and thus, the loss of volatiles increases for thin layers of oil as compared to the situation with oil in bulk (Cormack, 1999). The presence of volatile components in the early stages of the oil spill incident can increase the risk of oil combustion (Cormack, 1999).

2.3.3 Viscosity

Viscosity is the measure of the flow properties of the oil/material (Cormack, 1999). Low viscosity implies a mobile liquid and high viscosity denotes the materials that are resistant to flow, such as heavy fuel oils (Cormack, 1999). Most of the crude oils and refined products have viscosities from approximately 5 to 25000 centistokes at 15°C (Nordvik et al., 1996). Viscosity of an emulsion is governed by the factors stated below (Johnsen and Ronningsen,2003).

- Viscosity of the continuous phase
- Viscosity of the dispersed phase
- Volume fraction of the dispersed phase
- Temperature
- Average droplet size and size distribution
- Presence of solids in addition to the dispersed phase liquid
- Shear rate

- Nature and concentration of the emulsifying agent

As the crude oil weathers, its viscosity increases due to the progressive loss of the light volatile (lower molecular weight) fractions (Doerffer, 1992). Viscosity increases with decrease in temperature (Cormack, 1999). Evaporation and emulsification increases the viscosity of the fresh spilled oil (Cormack, 1999).

2.3.4   Flash point

The temperature at which the vapor of the oil will ignite, when exposed to an ignition source is called flash point of the oil (Doerffer, 1992). Light oils can ignite under most ambient conditions, however bunker and other heavy fuel oils do not cause a serious fire hazard when spilled on the seawater surface (Doerffer, 1992).

2.3.5   Emulsification

When the floating oil is exposed to the underlying seawater and is subjected to agitation by turbulence, it promotes the entry of water drops into the oil phase to form w/o emulsions (Cormack, 1999). Water in crude oil emulsion involves dispersion of water droplets into the continuous phase of the crude oil (Wei et al., 2003). The dispersed phase droplets are prevented from coalescing, and therefore from separating by a layer of surface-active agents present naturally in the crude oil (Pekdemir et al., 2003). The loss of volatiles during evaporation and the uptake of seawater are the two main factors that results in the formation of viscous emulsions (Cormack, 1999). The density of the resultant emulsion can be as high as 1.03g/ml (Fingas and Fieldhouse, 2003). The viscous water in oil emulsions formed are undesirable as they not only cause serious processing problems but also lead to significant cost increases for pumping, transportation, and other difficulties (Pekdemir et al., 2003). The water content in such emulsions can be as much as 60 to 70 percent in volume (Ronningsen, 1992). Thus, emulsification is a major weathering process, which not only increases the volume of the pollutants but also renders the oil much more viscous than the original oil released (Cormack, 1999).

2.3.6   Emulsion breaker

The emulsions formed on the sea after oil spills are inherently stable. Emulsion breaking is one of the most complex processes in the oil industry. Breaking of water in crude oil emulsions involves chemical, thermal, electrical, or a combination of these processes depending on the characteristics and properties of the emulsion (Mohammed et al., 1993). Various methods of demulsification, like centrifugation, sedimentation, heating, use of dispersants and emulsion breakers have been examined (Kim et al., 2002). Amongst these techniques, heating and centrifugation did not gain much acceptance due to the high cost and energy requirements. The realization that dispersants cannot deal with higher viscosity emulsions, encouraged the investigation of the possible application of emulsion breakers (Cormack, 1999). The addition of chemical demulsifiers in small quantities can greatly facilitate oil-water separation (Poindexter and Lindemuth, 2004). According to Nordvik et al. (1996), the main advantages of using emulsion breakers are:

1. Rapid and cost effective
2. Reduction in the viscosity of crude oil emulsions
3. Improve pump-ability
4. Reduce oil waste handling
5. Reduces the final disposal cost by a factor of 10.

Breaking of such emulsions also requires introduction of some turbulent energy (Lane, 1995). The energy requirement is variable and depends upon the type of energy induction and the type of emulsion breaker used (Lane, 1995). The main objective of the emulsion breaker/demulsifier is to displace the naturally occurring emulsifying agents from the oil-water interface (Cormack, 1999). Nordvik et al. (1996) stated that the efficiency of the emulsion breakers depends upon:

1. The efficiency of the product (emulsion breaker)
2. Oil characteristics
3. Environmental conditions
4. Application method
5. Time of application

2.4   INDUCTION HEATING

2.4.1   Physical principles

2.4.1.1 Electromagnetic induction

Inductive heating means heating system of different objects. These are commonly elements which are heated with a frequency within the range 50 Hz to 3 MHz, either thoroughly with respect to the plastic working or to the heat treatment of the metal element, or are heated on the surface only for the purpose of hardening (Andrzej Sluzalec., 1988). Thus, the induction heating process has been widely applied in industrial operations. Then, the basic principles of induction heating are Faraday's and Ampere's law.
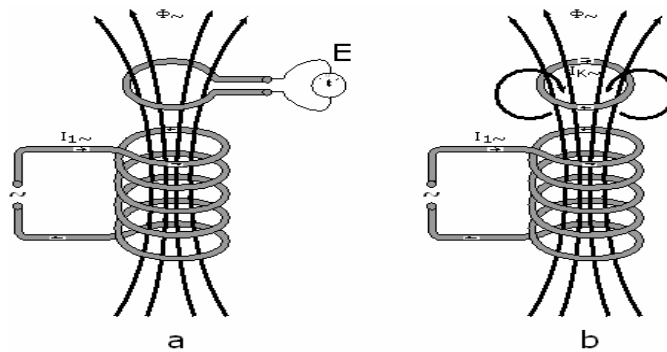

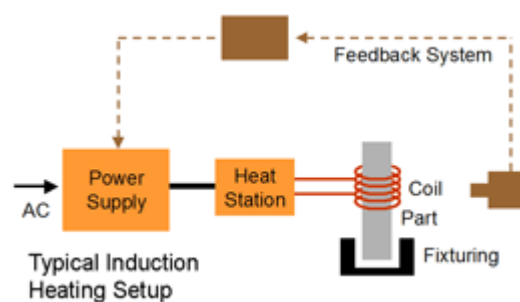Figure 2.1: Induction law of Faraday

Figure 2.2 : Typical induction heating set up

If a 'massive' conductor (e.g. a cylinder) is placed in the alternating magnetic field instead of the sort circuited loop, than eddy currents (Foucault

currents) will be induced in here (see Figure 2). The eddy currents heat up the conductor according to the Joule effect.

From these general laws of physics, it is demonstrated that an alternating voltage applied to the induction coil can produce an alternating magnetic flux, which produces an alternating voltage at the same frequency with the current of the coil. According to the Lentz's law, the time-varying electro-magnetic field will induce the eddy current, which can generate a flux opposite to the direction of the coil flux. The eddy current then produces heat by the Joule effect.
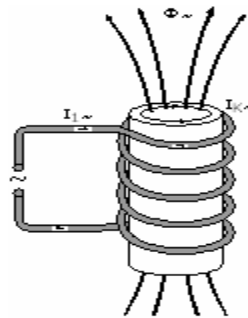

Figure 2.3: Induction of eddy currents

Although induction heating has been successfully applied in many industry process such as induction metal melting, and it's utilization in mold surface heating need to overcome several concerns including coil design, system operation and parameters control. For many different purposes of the induction heating process, the design of the heating system could be complex and had to rely upon a trial and error process. Therefore, it is necessary to build a precise and suitable numerical simulation module for the investigation of the induction heating process (Jiin-Yuh Jang et al., 2007).

2.4.1.2 The joule-effect

When a current I flows through a conductor with resistance R, the power is dissipated in the conductor.

$$P = R \times I^2$$

In most applications of induction heating the resistance R cannot be determined just like that. The reason is the non-uniform distribution of current in the conductor.

2.4.1.3 Penetration depth

Induction heating is one of a method which providing fast, consistent heat for manufacturing applications which involved bonding or changing the properties of metals or other electrically conductive materials. Other than that, the process relies on induced electrical currents within the material to produce heats. Then, the workpiece is placed in the coil where this field induces eddy currents in the workpiece, then generating precise, clean, non-contact heat in the workpiece. Then, induced current in the workpiece is most intense on the surface and diminishing below the surface; 80% of the heat produced in the part is produced in the outer 'skin'. Therefore, this is called the *skin effect* and the skin effect is characterized by its so called *penetration depth,* d. So, the penetration depth is defined as the thickness of the layer, measured from the outside, in which 87% of the power is, developed (Figure 3).
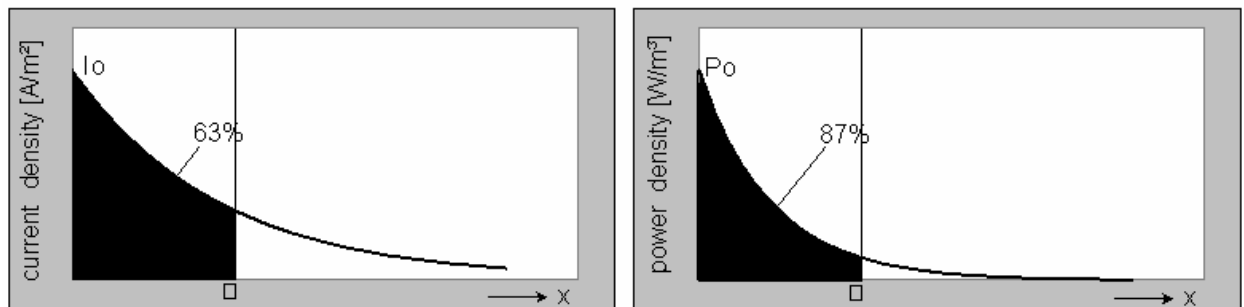

Figure 2.4: Penetration depth

The penetration depth can be deduced from Maxwell's equations. For a cylindrical load with a diameter that is much bigger than d, the formula is as follows

$$\delta = \sqrt{\frac{\rho}{\pi.\mu.f}}$$

⬜⬜: resistivity [⬜.m]

⬜⬜: magnetical permeability [H/m] (⬜=⬜o.⬜r)

t: frequency [Hz]

We can see that the penetration depth, on the one hand, depends on the characteristics of the material to be heated (⬜, ⬜) and, on the other hand, is also influenced by the frequency. The frequency dependence has offers a possibility to control the penetration depth.

The following table gives an idea of the order of magnitude of ⬜.

Table 2.2 : Penetration depths

δln(mm)	Steel 20˚C	Steel 20˚C	Copper 20˚C	Copper 900˚C	Graphite 20˚C
ρ (µΩ.m)	0.16	0.16	0.017	0.086	10.00
μ_r	40	100	1	1	1
Frequency Hz					
50	4.50	2.85	9.31	20.87	225.08
100	3.18	2.01	6.58	14.76	159.15
1k	1.01	0.64	2.08	4.67	50.33
10k	0.32	0.20	0.66	1.48	15.92
100k	0.10	0.06	0.21	0.47	5.03
1M	0.03	0.02	0.07	0.15	1.59

As can be derived from the formula above, the penetration depth is inversely proportional to the square root of ⬜r.

2.4.2 Properties of induction heating

2.4.2.1 Characteristics of induction heating

Technically, induction process releases a quick heating because of the high power density installation. So, it offers the possibility to reach very high temperatures. Then, induction heating can be applied very locally and also the

installations are suited for automation. Next, inducting heating can reduce electrical energy consumption. The reason is because induction installations generally have a good efficiency. However, the efficiency is also depends on the characteristics of the material to be heated and also an important part of the heat losses can be recuperated. The third one is about the quality of the product by assisted this process. An extreme purity is possible by working under vacuum or inert atmospheres. Since it is non-contact process, the heating process does not contaminate the material being heated. Another is, the place of heating can be determined accurately and can be regulated precisely. Then, based on the environment and working condition, there is no production of flue gases.

2.4.2.2 Power transfer: simplified calculation

The load of an induction installation is heated because of the Joule effect as a result of induced eddy currents. The simple formula $P=R{\times}I^2$ cannot be used because the distribution of the currents over the conductor is not uniform.

In General, one can state:

$$P \; = \; \pi.d.h.H^2.\sqrt{\pi.\rho.\mu_o.\mu_r.f.C.F}$$

d: diameter of the cylinder [m]
h: height of the cylinder [m]
H: magnetic field intensity [A/m]
μ_r: relative permeability
μ_o: magnetic permeabity of vacuum
f: frequency [Hz]
C: coupling factor
F: power transmission factor

Conclusions resulting from these formulas are the power can be increased by an increase in the magnetic field intensity H. This means increasing the number of ampere-windings of the inductor; an increase of the frequency only leads to a

relative small increase in the power. Moreover, the losses in the supply increased and the penetration depth gets smaller; material characteristics play an important part (r and especially μ_r). For ferromagnetic materials the added power drops when the Curie temperature is exceeded (μ_r=1 if T>T$_{\text{Curie}}$).

2.5   THEORIES

2.5.1 Derivation of the heat equation

The heat equation follows from the **conservation of energy** for a small element within the body,

$$
\begin{array}{l}
\text{heat} \\
\text{conducted} \\
\text{in}
\end{array}
+
\begin{array}{l}
\text{heat} \\
\text{generated} \\
\text{within}
\end{array}
=
\begin{array}{l}
\text{heat conducted} \\
\text{out}
\end{array}
+
\begin{array}{l}
\text{change in} \\
\text{energy} \\
\text{stored} \\
\text{within}
\end{array}
$$

(Source :)

We can combine the heats conducted in and out into one "net heat **conducted** out" term to give,

$$
\begin{array}{l}
\text{Net} \\
\text{heat} \\
\text{conducted out}
\end{array}
=
\begin{array}{l}
\text{heat} \\
\text{generated} \\
\text{within}
\end{array}
-
\begin{array}{l}
\text{Change in} \\
\text{energy} \\
\text{stored within}
\end{array}
$$

(Source :)

2.5.1.1 Heat conduction

Heat transfer by conduction can be used to model heat loss through a wall. For a barrier of constant thickness, the rate of heat loss is given by:
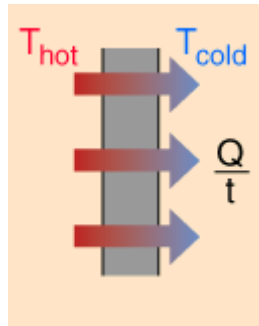
Figure 2.5 : Conduction heating

$$\frac{Q}{t} = \frac{kA(T_{hot} - T_{cold})}{d}$$

Q = heat transferred in time = t

k = thermal conductivity of the barrier

A = area

T = temperature

d = thickness of barrier

Table 2.3 : Material thermal conductivity

Material	Thermal conductivity (cal/sec)/(cm² C/cm)	Thermal conductivity (W/m K)*
Diamond	...	1000
Silver	1.01	406.0
Copper	0.99	385.0
Gold	...	314
Brass	...	109.0
Aluminum	0.50	205.0
Iron	0.163	79.5
Steel	...	50.2
Lead	0.083	34.7
Mercury	...	8.3
Ice	0.005	1.6
Glass,ordinary	0.0025	0.8
Concrete	0.002	0.8
Water at 20° C	0.0014	0.6
Asbestos	0.0004	0.08
Snow (dry)	0.00026	...
Fiberglass	0.00015	0.04
Brick,insulating	...	0.15
Brick, red	...	0.6

2.5.1.2 Heat convection

I.   Forced or Assisted Convection

Forced convection occurs when a fluid flow is induced by an external force, such as a pump, fan or a mixer

II. Natural or Free Convection

Natural convection is caused by buoyancy forces due to density differences caused by temperature variations in the fluid. At heating the density change in the boundary layer will cause the fluid to rise and be replaced by cooler fluid that also will heat and rise. This continues phenomena are called free or natural convection. Boiling or condensing processes are also referred as a convective heat transfer processes.

The equation for convection can be expressed as:

$$q = k \, A \, dT$$

Where

q = heat transferred per unit time (W)

A = heat transfer area of the surface (m^o)

k = convective heat transfer coefficient of the process (W/m^{2}K or W/m^{2o}C)

dT = temperature difference between the surface and the bulk fluid (K or ^{o}C)

(Source :

Heat Transfer Coefficients - Units

- 1 W/m^{2}K = 0.85984 kcal/h m^2 ^{o}C = 0.1761 Btu/ ft^2 h ^{o}F
- 1 Btu/ft^2 h ^{o}F = 5.678 W/m^2 K = 4.882 kcal/h m^2 ^{o}C
- 1 kcal/h m^2 ^{o}C = 1.163 W/m^{2}K = 0.205 Btu/ ft^2 h ^{o}F

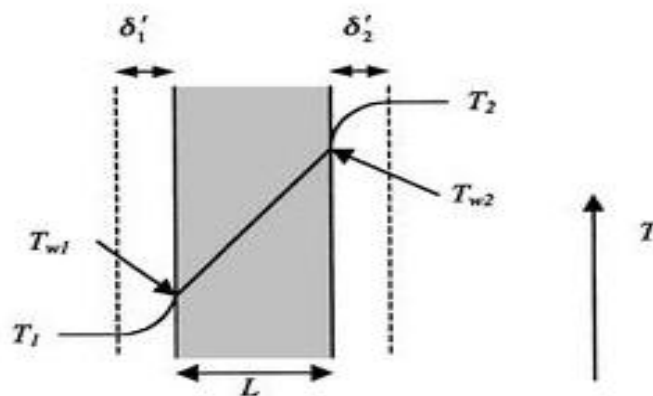**2.5.1.3   Combined of conduction and convection heat**

Figure 2.6: Conducting wall and convective heat transfer

The heat transfer in fluid 1 is given by

$$\frac{\dot{Q}}{A} = h_1(T_{w1} - T_1).$$

This is the heat transfer per unit area to the fluid. The heat transfer in fluid 2 is similarly given by

$$\frac{\dot{Q}}{A} = h_2(T_2 - T_{w2}).$$

Across the wall, we have

$$\frac{\dot{Q}}{A} = \frac{k}{L}(T_{w2} - T_{w1}).$$

The quantity $\dot{Q}/A$ is the same in all of these expressions. Putting them all together to write the known overall temperature drop yields a relation between heat transfer and overall temperature drop, $T_2 - T_1$:

$$T_2 - T_1 = (T_2 - T_{w2}) + (T_{w2} - T_{w1}) + (T_{w1} - T_1) = \frac{\dot{Q}}{A}\left[\frac{1}{h_1} + \frac{L}{k} + \frac{1}{h_2}\right]$$

We can define a thermal resistance, R, as before, such that

$$\dot{Q} = \frac{(T_2 - T_1)}{R},$$

Where R is given by

$$R = \frac{1}{h_1 A} + \frac{L}{Ak} + \frac{1}{h_2 A}.$$

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this study, there will be two simulation processes. The first is the simulation will be on the hybrid induction heating distillation and the second simulation will be done for the typical distillation process. These simulations will be conducted to investigate the energy consumption and the distillation process efficiency. Matlab simulation will be use as a tool for the simulation of the distillation process. The comparison between these two distillation process will help in achieving the objectives of the study.

3.2   SIMULATION PROCEDURE

The simulation will be conducted by using Matlab simulation. Benzene-toluene mixture from the pond oil will be the element to test the distillation process. The simulation is perform twice, first for the hybrid induction heating distillation, and second for the typical distillation process. Prior the simulation process, list of equation for the hybrid induction heating distillation and the typical distillation will be inserted to the Matlab simulation. Important variable, such as the boiling point of water, boiling point of oil and others will also be programmed.
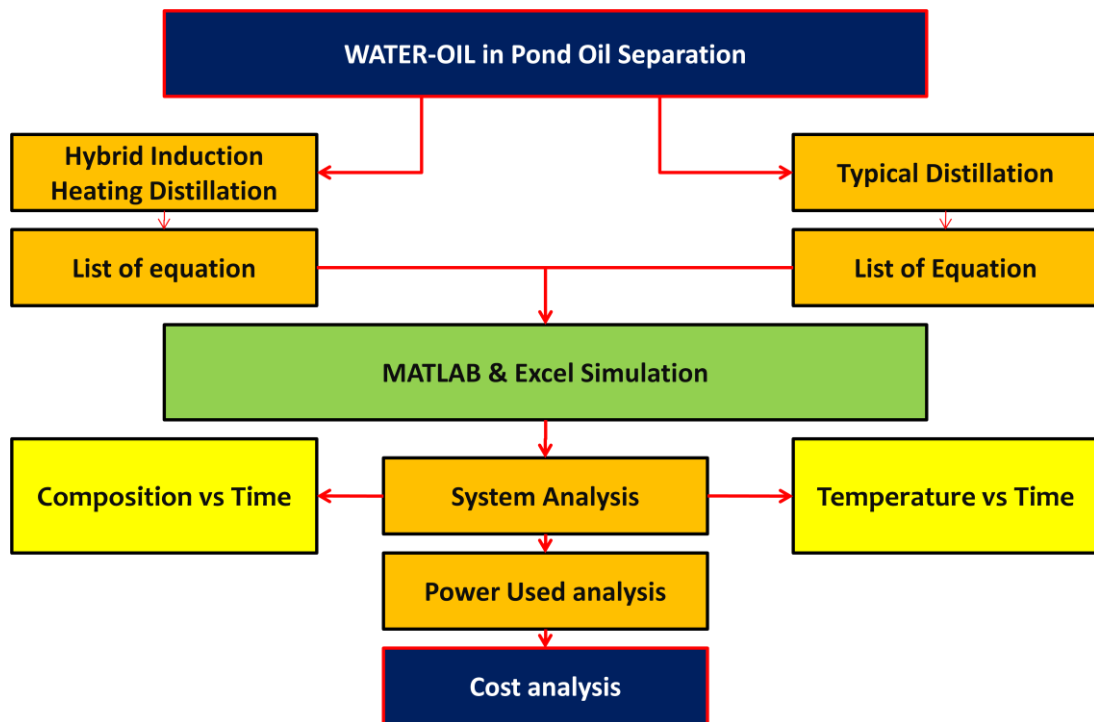
Figure 3.1 : Methodology

3.3 SIMULATION CONCEPT

The concept of simulation is, the characteristics(boiling point or etc.) of water-oil mixture will be programmed, and the result will base on the water distilled. For the result measurement, it will base on the temperature, time, heat and energy required for the distillation process.
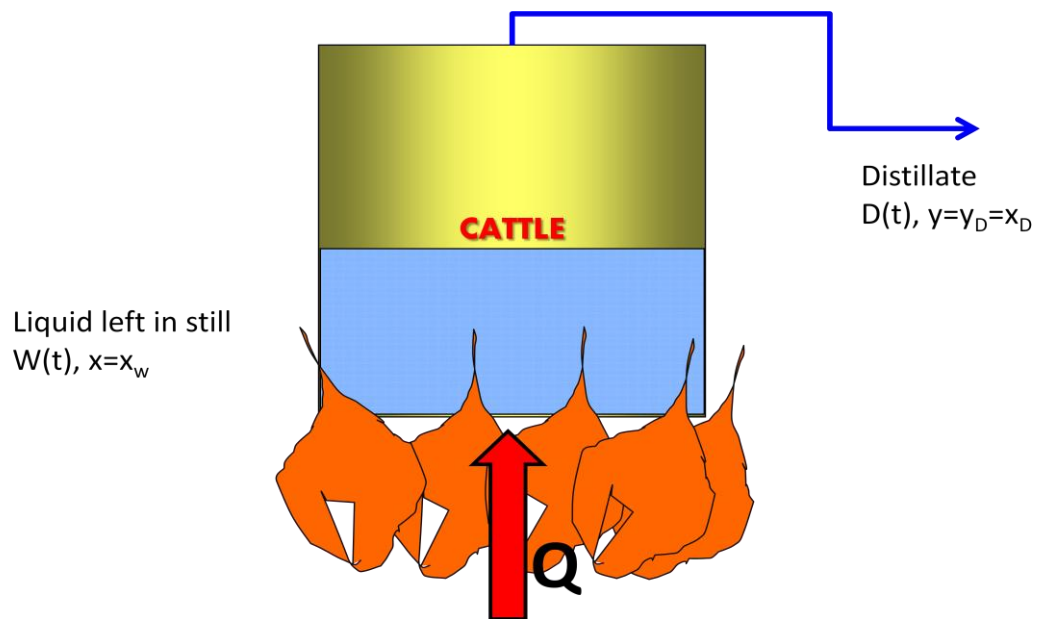
3.3.1 Typical distillation

Figure 3.2 Typical distillation

Typical distillation process is a distillation process using heating element like boiler, heater or direct flame to heat up the fluid in the distillation column. The benzene and toluene mixture will heat at 105^OC. Then, we will analyzed how long is the time taken for complete distillation to occur.
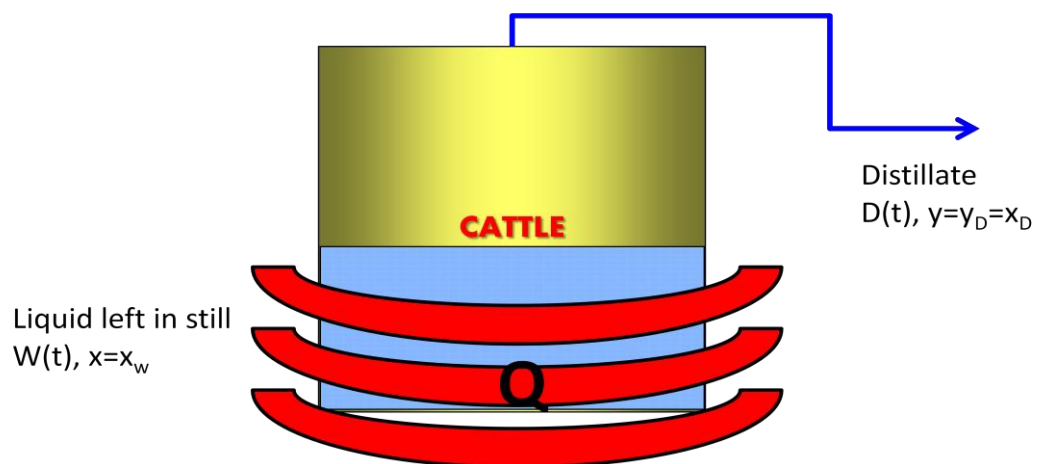
3.3.2 Induction heating technique

Figure 3.3 Induction heating distillation

The induction heating technique is a heating technique for electrical conductive materials (metals). Induction heating is frequently applied in several thermal processes such as the melting and the heating of metals. For this research, we will use induction heating coil to heat up the water in the vessel. The coil will be put into the mortar stone as the medium to heat the vessel.

I.   The frequency will set to 50 Hz (constant)

For this method we will investigate at which temperature will produce the highest amount of distilled water. The temperature of the water in simulation will be increase, so we will be more focused on the temperature at $80^{O}C$, $90^{O}C$ $100^{O}C$ and $110^{O}C$. Because, the boiling point of water is 100°C or 212° F at 1 atmosphere of pressure (sea level). The boiling point of water also depends on the purity of the water. Water which contains impurities (such as salted water) boils at a higher temperature than pure water. This phenomenon is called boiling point elevation.
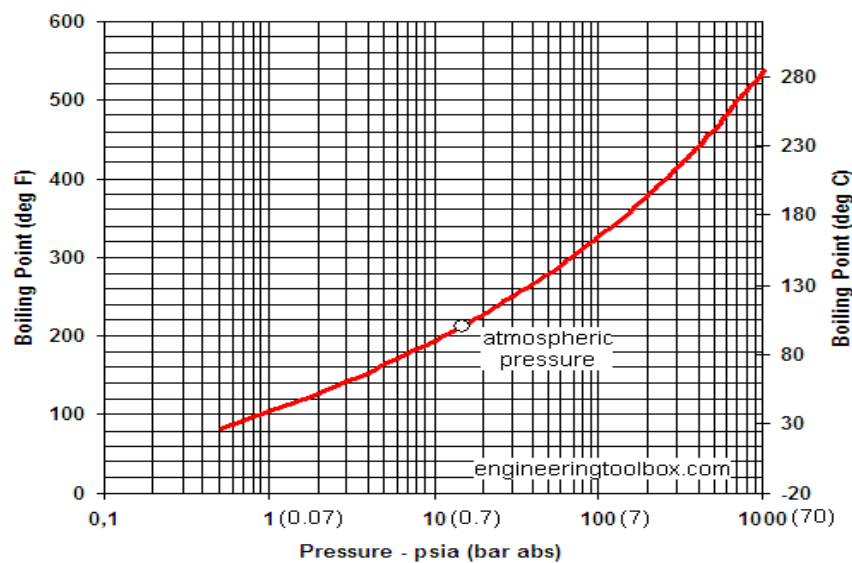

Figure 3.4 : The boiling point depends on the pressure and the boiling points of water at pressures ranging *0.5 - 1000 psia* are indicated in the diagram.

II.   The temperature will set at a constant value

The temperature will set up at 105^OC and the frequency will set in range of 50 Hz. The purpose of this method is analyzed at what frequency that the product will produce at the best results the volume of the product.

3.3.3 Adjustment of the simulation

For this experiment, since the detail of composition mixture inside the pond oil utilities is various and limited reference to search on the physical and chemical properties. Therefore, it is decided to change the mixture to the benzene and toluene mixture.

The adjustment that has been made was mixture is a binary mixture with different boiling point, distillation type is batch distillation and batch still is loaded with 100 kmol 50% benzene in toluene with a relative volatility = 2.41.

3.3.4 Process model of batch distillation process

In differential distillation a feed mixture (an initial charge) of a given composition is placed in a single stage separator (a still pot, retort or flask) and heated to boiling. The vapor is collected and condensed to a distillate. The composition of the remaining liquid and the distillate are functions of time. There may be several reasons for running a batch process such as this:

1) Small capacity doesn't warrant continuous operation

2) Separation is to be done only occasionally

3) Separation is preparative to produce a new product

4) Upstream operations are batchwise or feedstocks vary with time or from batch to batch

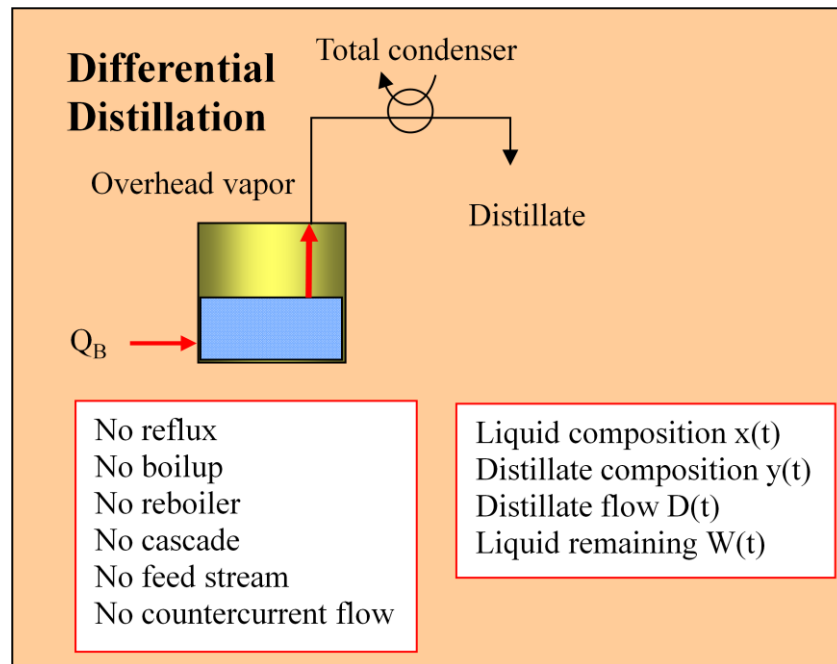5) Feed materials are not appropriate for a continuous flow system.

Figure 3.5 Batch distillation model

The model of cattle is specified according to the table below :

Table 3.1 : Cattle data specification and characteristic

DATA	
Diameter, d	0.5 m
Height, h	0.5 m
Wall Thickness	0.5cm
Type	Stainless steel
Density	7849 kg/m^3
Specific Heat,Cp	0.4606 kJ/kg.K
Material Resistivity,R	0.126 Ω

3.3.6   List of equations

(i)   Batch Distillation process

Rate of depletion of component is the liquid form is given by :

$$-\frac{d}{dt}(Wx_W) = -W\frac{dx_W}{dt} - x_W\frac{dW}{dt}$$

Rate of depletion equals the component flow rate in distillate

$$-\frac{d}{dt}(Wx_W) = -W\frac{dx_W}{dt} - x_W\frac{dW}{dt} = Dy_D$$

$$Wdx_W + x_W dW = y_D dW$$

The volatility of the mixture

$$y_A = \frac{\alpha_{AB}x_A}{1 + x_A(\alpha_{AB} - 1)}$$

The average composition of liquid and vapor during the process

$$(x_D)_{avg} = (y_D)_{avg} = \frac{W_0 x_0 - Wx}{W_0 - W}$$

The time taken to distillate at specific time

$$t = \frac{w_0}{D}\left\{1 - \exp\left\{\frac{-1}{(\alpha - 1)}\left[\ln\frac{x_0}{x} + \alpha\ln\frac{(1-x)}{(1-x_0)}\right]\right\}\right\}$$

(ii)   Induction power heat transfer

$$P = I^2 R = q\dot{\pi}V$$

CHAPTER 4

RESULT AND DISCUSSION

4.1   RESULT AND DISCUSSION

For the result of the experiment, it is simplified by the table 4.1, and the simulation is shown in the appendix A. in the table, X is refer to the composition of liquid benzene meanwhile Y is the composition of vaporized benzene. The initial composition of benzene is 0.5, the relative volatility 2.41, the initial weight is 100kg and the separation rate is 10 kmol/hr

Table 4.1 : Overall summary of the distillation simulation

| Liquid composition,X	Weight,W	Gas Composition,Y	Time Induction	Time LPG	Temperature,˚C
0.5	100	0.706745	0	0	25
0.475	88.71233	0.685582	1.128767	16	81.4
0.45	78.84945	0.663506	2.115055	16.98629	82.7
0.4	62.50739	0.616368	3.749261	18.62049	85
0.35	49.5891	0.564781	5.04109	19.91232	87.3
0.3	39.16476	0.508082	6.083524	20.95476	89.7
0.25	30.58615	0.445471	6.941385	21.81262	92.3
0.2	23.38229	0.375975	7.661771	22.533	95.1
0.15	17.19001	0.29839	8.280999	23.15223	98
0.1	11.69391	0.211218	8.830609	23.70184	101.5
0.05	6.521221	0.112564	9.347878	24.21911	105.3

4.1.1   Composition against time
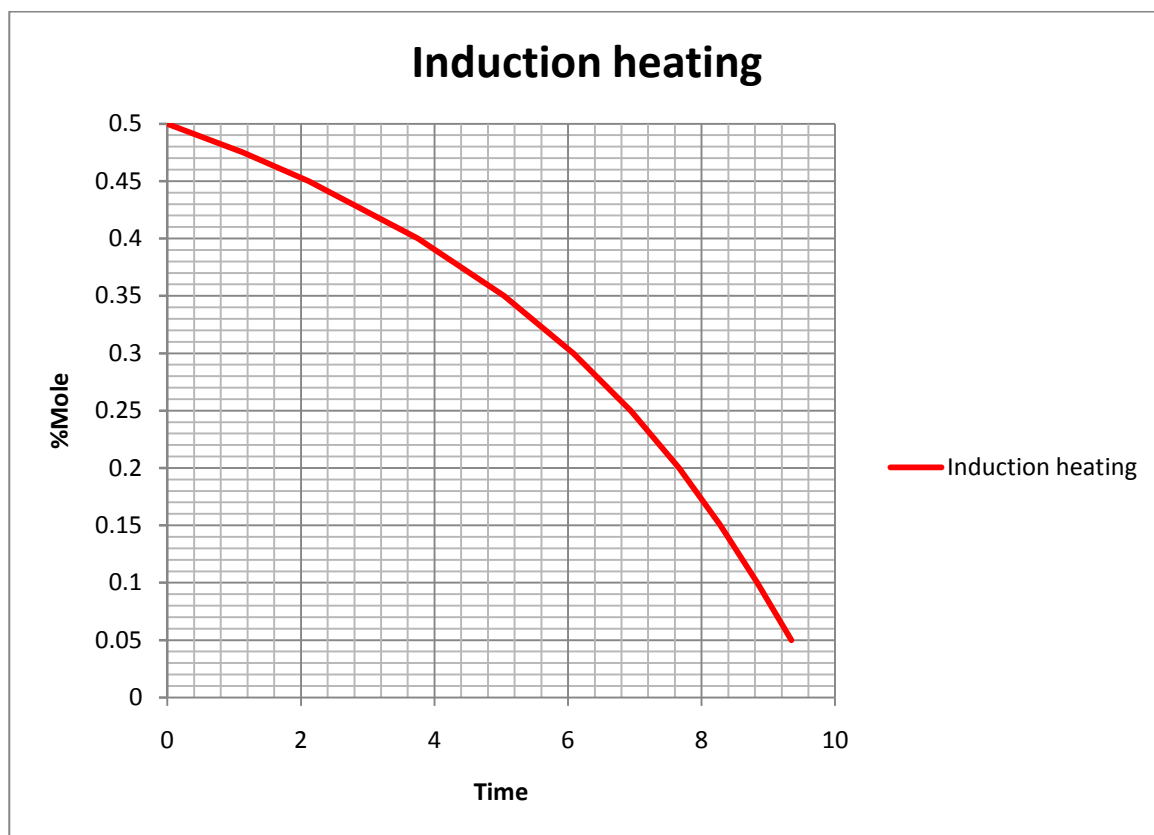
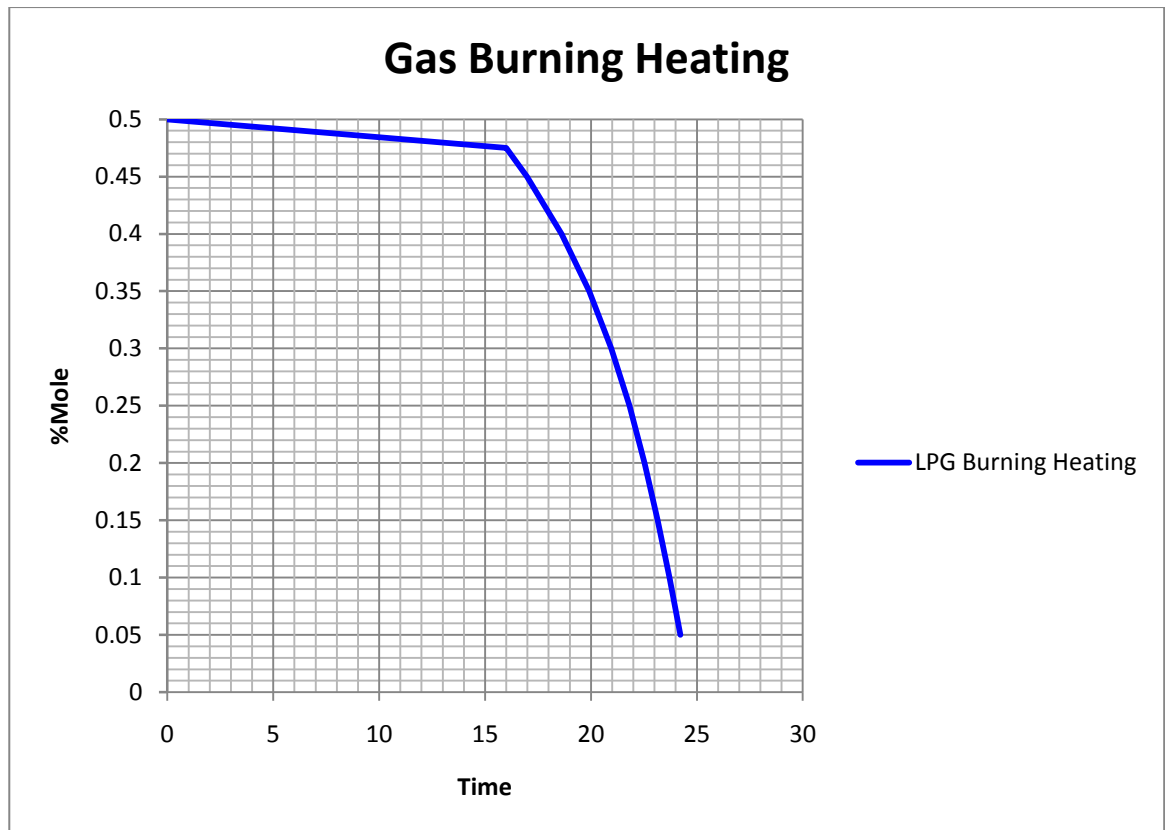Figure 4.1a : Concentration against time(Induction heating)

(***)

Figure 4.1b : Concentration against time(Typical distillation)

From the figure, it is reveal that the induction heating rate is faster that the rate of the process for the typical distillation. As we can see, the induction heating only took approximately 10 minutes to complete the distillation process, meanwhile, the gas burning heating took approximately 25 minutes to complete the distillation process. This shows that the induction took less time to complete the distillation process. This is because, the induction heating process reached the desired temperature faster than the typical distillation. For the Temperature against time will be discuss in the next section

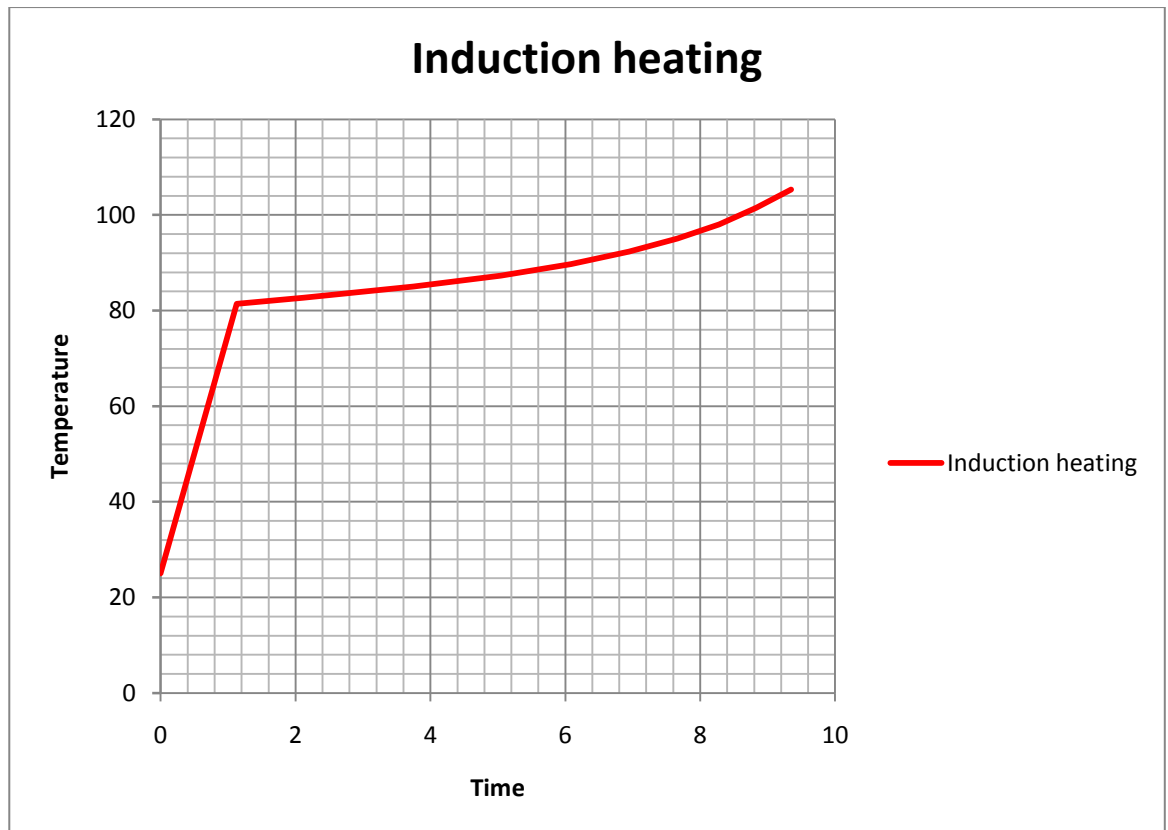4.1.2   Temperature against time

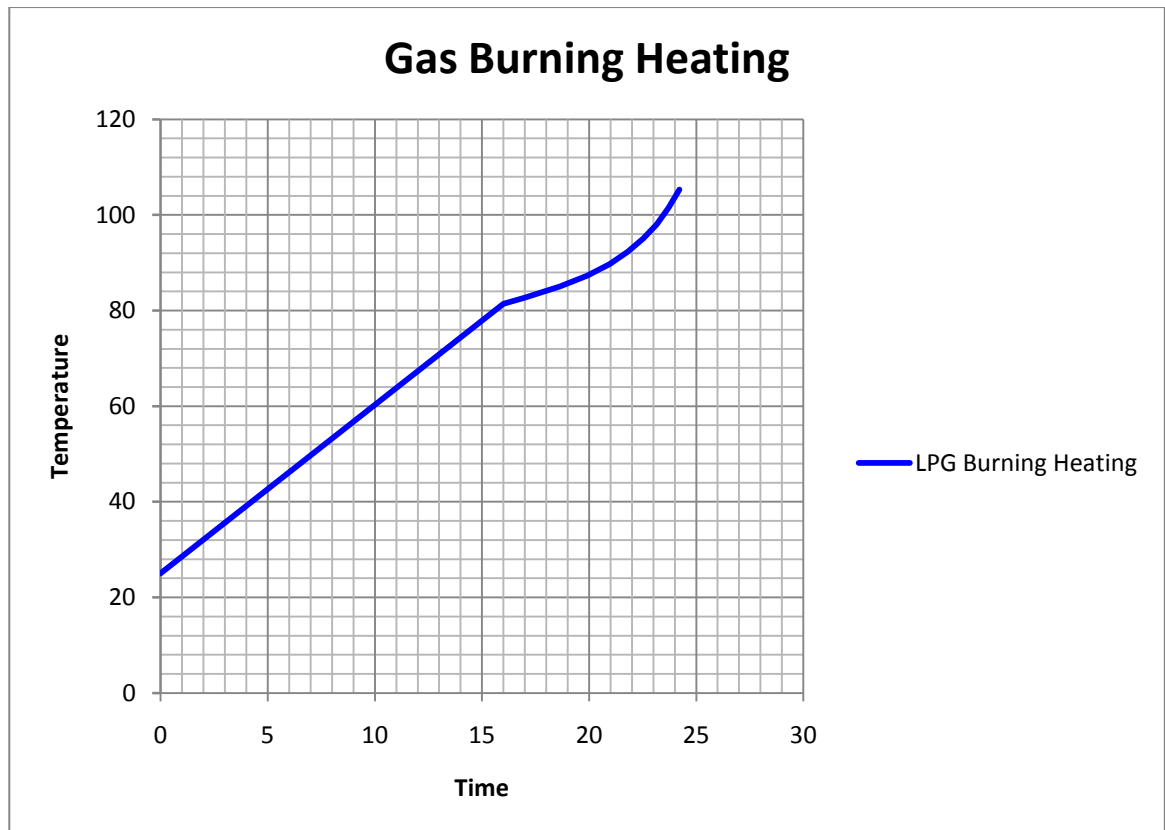Figure 4.2a : Temperature against time(Induction heating)

(***)

Figure 4.2b : Temperature against time(Typical heating)

From the figure above, it is shown that, the Induction heating process took less time to reach the desired temperature, this are the reason why the induction heating took less time to perform the distillation process. This is because, the induction heating has higher power density which lead to high temperature elevation.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 CONCLUSION

The conclusions are hybrid induction heating distillation is the better choice for obtaining the higher efficiency of distillation process, this is due to the higher power density which result higher temperature elevation .

Another is, induction heating is one of an efficient method for heating system. Refer on the results, the temperature is increased gradually with times but at certain scale, the temperature did not raised consistently. This is maybe because of surrounding factor. But, practically induction process release a quick heating because of the high power density installation and it offers the possibility to reach very high temperatures. Thus, inducting heating can reduce electrical energy consumption because of induction installations generally have a good efficiency.

Hybrid induction heating will help in reducing cost of the distillation process as it require less energy for the distillation as compared to the typical distillation. Hence, this will reveal the reliability of the hybrid induction heating.

5.2 RECOMMANDATION

For the further studies and for the application of the industry, some recommendations are advisable to make sure the system operates efficiently.

(i) The selection of metal for the coil and cattle must be study first as it has difference heat capacity , conductivity and resistivity.

(ii) In simulating Matlab, special course must be given as the matlab has multi-function.

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APPENDIXES

PROJECT SCHEDULE

TASK	MONTH									
	SEPT	OKTOBER	NOVEMBER	DISEMBER	FEBRUARY	MARCH	APRIL	MAY	JUN	JULY
TITLE SELECTION	■									
TITLE ACQUIRING	■									
MEETING WITH THE SUPERVISOR	■	■	■	■						
FIND THE COMPATIBLE JOURNALS	■	■	■							
RESEARCH PROPOSAL PREPARATION	■	■	■							
SLIDE PRESENTATION PREPARATION		■	■							
PSM PRESENTATION			■							
SUBMIT THE FINAL RESEARCH PROPOSAL				■						
INDUSTRIAL VISIT FOR POND OIL COMPOSITION AND PROPERTIES					■					

PROPERTIES AND EQUATION ANALYSIS				
MATLAB SIMULATION RUN				
ANALYSIS OF SYSTEM				
ANALYSIS OF ENERGY CONSUMPTION				
HEAT PENETRATION DEPTH AND RELAX TIME EVALUATION				
RESULT ANALYSIS & FINAL PRESENTATION				

Appendix B

Matlab Simulation Code

```matlab
clear all
%--Liquid & Gas composition data for Benzene & Toluene--%
X= [0.000 0.100 0.200 0.300 0.400 0.500 0.600 0.700 0.800 0.900 0.950 1.000];
%Composition of liquid (Benzene)
Y= [0.000 0.208 0.372 0.507 0.612 0.713 0.791 0.857 0.912 0.959 0.980 1.000];
%Composition of gas (Benzene)
T= [110 105.3 101.5 98.0 95.1 92.3 89.7 87.3 85.0 82.7 81.4 80.1];
%Boiling points of mixtures

%--------Data of Distillation Tower----------%
F=100; %Feed rate (kmol/hr)
D=10; %Product Rate (kmol/hr)
Xf=0.50; %Feed composition
Xd=0.98; %Distillate composition

%---------Calculate W, Xw and coefficients of BOL--------%
W=F-D; %Bottom Flow Rate (kmol/hr)
Xw=(F*Xf-D*Xd)/W; %Bottom Composition

%----------Polynomials of Equilibrium Curves-----------%
A= polyfit(X,Y,5);
%Coefficients of the Polynomial (Y vs X)
B= polyfit(X,T,5);
%Coefficients of the Polynomial (Temperature vs. X)
comp_temp=zeros(50,2);
```